

# **MODIFIED ABRASIVE BLAST/CHEMICAL STABILIZER ADMIXTURES FOR REMOVAL OF LEAD-BASED PAINT**

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## **BACKGROUND**

The U.S. Government maintains a large inventory of structures (buildings, equipment, bridges, dam gates, etc.) that contain lead-based paints (LBP) on their surfaces. LBP was conventionally used in the construction industry due to its excellent corrosion protection capabilities and tolerance of less-than-perfect surface preparation. The use of LBP has been banned for residential structures and consumer products, and industrial use is rapidly declining. However, old LBP remains on surfaces of many structures and continues to be a problem as these structures require maintenance and repainting. Due to the toxicity of lead, tight environmental regulations control paint removal operations that involve LBP to ensure that surrounding air, lead, and water environments are not contaminated.

The U.S. Environmental Protection Agency (USEPA) regulates the disposal of the waste generated from LBP abatement projects, and the type of containment necessary to protect the surrounding environment. The amount of airborne lead is regulated, and the disposal procedures for the waste depend upon the level of leachable lead in the material.

Extensive research has been performed to find methods to remove LBP from structures without harming the environment, workers, or surrounding communities. USACERL evaluated one method involving the abrasive blasting of a properly enclosed structure using an engineered abrasive.<sup>1</sup> The engineered abrasive has been shown to

stabilize LBP waste from abrasive blasting so that the waste will not be classified as hazardous. In response to this research, the USEPA approved the processing of Blastox®-treated LBP waste that passes the Toxicity Characteristic Leaching Procedure (TCLP, USEPA Method 1311) as nonhazardous for lead. The Steel Structures Painting Council (SSPC) has also approved the use of Blastox® to stabilize leachable lead.<sup>2</sup> Since the use of engineered abrasives is broadly applicable to steel, concrete and wood structures, they promise to play an important role in LBP abatement throughout the spectrum of Government- or industry-owned structures in the United States.

## **OBJECTIVE**

The objective of this research was to modify existing chemical stabilizer/abrasive blast admixtures to enable removal of LBP from structural steel in immersion service, such as Corps of Engineers (COE) lock and dam gates, water storage tanks, and bridges. The modified abrasive blasting admixture is intended to stabilize the heavy metal paint waste (e.g. form and insoluble metallic silicate complex) during the removal process, so that the waste can be disposed of as non-hazardous.

## **APPROACH**

A series of laboratory experiments were conducted to optimize the blend ratios of the chemical stabilizer with different abrasive blast media. The abrasives were used to blast coated test panels. The panels were then repainted with standard Corps of Engineers paint systems and subjected to accelerated weathering tests, salt fog chamber exposure, and immersion tests, to determine if there were any coating performance problems associated with the abrasive blasting process.

Based on the blast media and coatings tests, a field demonstration was conducted at a dam gate in the Portland District. LBP was removed using four different engineered abrasive blends, and two different blast procedures. TCLP tests were performed on the waste. USEPA and Occupational Safety and Health Administration (OSHA) site and worker air-monitoring and blood tests were conducted to evaluate the impact of the process on the environment and the workers. After the field demonstration, the lead leachability and reuse options of the non-hazardous wastes were evaluated.

The field demonstration and the project were completed when USACERL and Portland District personnel visited the site after a year of immersion service. They evaluated the performance of the coating system applied after blasting with the engineered abrasives. The condition of the coating was compared to that of a surface prepared with traditional blast media and blasting methods.

## **RESULTS OF LABORATORY RESEARCH**

### **BLASTING ADMIXTURE DEVELOPMENT**

Satisfaction of industry requirements determined the actual design of the admixture, as well as the markets where the technology was best applied. For an abrasive to be modified by the addition of a chemical stabilizer, the "engineered abrasive" had to meet the following requirements:

- The technology must have abrasive cutting characteristics.
- The technology would have to limit the measured leachability of the lead in the waste.
- The technology could not meaningfully increase worker safety concerns.
- The technology cannot have a material negative effect on coating performance.
- The technology cannot impede normal paint removal operations (i.e., no excessive dusting, no unusual application requirements, etc.).

Silicate stabilization has been identified as a desirable approach. The challenge was to find an effective method for delivering the treatment to the process. Traditional blasting operations using dry blasting technologies require the abrasive media to be dry and free flowing. The use of any liquid additive to the abrasive media would therefore require blending with or application to the abrasive, as well as drying before use.

The industry then looked at calcium silicate granules as a source of dry reagent addition. Sources of reagent were identified, and the most cost-effective source for silicates is through cement production. In particular, cement clinker is a calcium silicate-rich material that is rock-like in consistency. TDJ, Inc. collected samples of clinker from various plants in the Midwest that produced No. 1 Portland cement. The material was

reduced in size to a sand-like consistency (12-50 mesh), and was evaluated for hardness using the Mohs hardness scale. This material had a Mohs hardness of between 6 and 7, which is harder than many sands, but is slightly softer than mineral slag abrasives. In short, the material tested with sufficient hardness to be suitable as an abrasive media.

#### ABRASIVE CUTTING CHARACTERISTICS

The material was then evaluated for general cutting characteristics. This evaluation involved the use of Blastox<sup>®</sup> to remove LBP from sample test panels. The material was observed to exhibit good cutting characteristics, suggesting that the angularity and friability of the material were acceptable for general use, and would not have a negative effect on performance when incorporated into traditional abrasive media.

#### LIMITING LEAD LEACHABILITY

The USEPA has identified silicates as a most desirable form of lead waste treatment. Cement clinker is rich in the silicates used for most cement-based stabilization processes. Through testing of leaded wastes with varying levels of contamination, TDJ observed that consistent success (lowering lead leachability to below 5 ppm in the TCLP test) began to occur with the addition of about 12 percent cement clinker. To allow for variations in homogeneity of the mix, a 15 percent addition rate, by weight, was recommended.

TDJ completed a series of tests that suggest that clinker fines (fines generated by abrasive reduction during the blasting process) do in fact act to effectively reduce the measured leachability of lead. A lead concentration of up to 35% by weight in the waste will be stabilized to leach less than 5 ppm in the TCLP test.

#### CHEMISTRY OF THE STABILIZATION REACTIONS

Based on the chemical composition of the additive and knowledge gained from the literature of the chemical reactions between calcium silicate materials and lead, a number of stabilization mechanisms were hypothesized. Within the cement system, there are several possible reactions, which may occur in many different combinations and affect the leachability of lead:

1. When initially placed in solution, Blastox® dissociates, creating carbonates and hydroxides in solution, which raise the pH of the solution to a range of 10.0 to 11.3. The effects of this are: (a) a pH above 10 promotes the hydration reactions of this product, and (b) lead pigments are amphoteric compounds, meaning they are soluble at low and high pH values but exhibit minimum solubility within the range of 8.0 to 11.0. This reaction aids the kinetics of the stabilization reactions by limiting the lead dissolution to assure that other reactions can occur quickly enough to stabilize all the free lead ions.
2. Due to the cementitious nature of the calcium silicate hydrate, the lead is immobilized upon wetting of the waste. In a landfill, these wet reactions tend to create a solid mass (hydrate), which limits the amount of water that could percolate. The Blastox® waste does solidify or set in a similar manner to Portland cement. Similar to cement, the strength of these encapsulation reactions depends on the waste/cement ratio, mixing, and set time.

One mechanism hypothesized involves the intermediate formation of lead carbonates. When cementitious materials are placed in solution, carbonates are dissolved. Free lead ions are also in solution due to the dissociation of lead oxide or lead hydroxide. The Free lead can react with the carbonates in solution, and precipitate as lead carbonates, which have limited solubility. The other mechanisms believed to occur in the system are the addition and cation substitution reactions between lead and calcium silicates, which create an insoluble lead silicate.

It is also hypothesized that, over time, the lead carbonate would be respeciated to a lead silicate. As the environment surrounding the waste fluctuates, the lead carbonates dissociate, causing the lead to redissolve, then react with the silicates. The end result of all of these reactions is believed to be a complex lead silicate. These hypotheses are consistent with the results of the laboratory analysis and the published literature, and no contradicting evidence was found.

#### COATING TESTS

One of the key limiting factors in the use of abrasive additives is the performance of the coating systems used to limit subsequent corrosion. The use of an additive may introduce a

contaminant to the surface that will allow or encourage the formation of corrosive cells and accelerate the failure of the paint system. A significant failure of the system will force cleaning and repainting of the structure. Before any new abrasive, additive or other modification is applied to the surface, laboratory and field analyses of coating performance is advisable. In the case of Blastox<sup>®</sup>, both approaches were used.

As a first screening method, Blastox<sup>®</sup>-treated metal surfaces were subjected to a series of accelerated weathering tests under a range of conditions. New steel panels were subjected to abrasive blasting through the use of a standard dry blast system. Black Beauty abrasive (12-40 mesh) was combined with Blastox<sup>®</sup> admixture at a ratio of 15% Blastox<sup>®</sup> by weight to 85% abrasive. The additive was uniformly mixed with the abrasive, and the blend was used to profile the steel. A parallel set of panels was prepared with unmodified Black Beauty abrasive. In both cases the steel was blasted until the surface profile was between 2.5 and 3.5 mm. Profiles were verified by direct surface measurement. The surfaces were coated with the following paint system:

- zinc rich epoxy
- polyamide epoxy
- titanium dioxide pigmented epoxy
- aluminum epoxy mastic

Each coating system was applied to a Blastox<sup>®</sup> treated panel and a panel treated with standard abrasive. Each system was allowed to cure per the manufacturer's instructions. Once the coating systems were cured, they were subjected to fresh water immersion and salt fog chamber accelerated exposure tests. After 30-, 60-, and 90-day exposure periods, the paint systems were subjected to visual inspection and adhesion testing. As a result of that testing the researchers concluded that all paint systems tested indicated acceptable laboratory performance with one exception: paint systems with a red iron oxide pigment. The researchers determined that a sweep blast with standard abrasive was sufficient to remove the offending residue. No other problems were noted.

#### DISCUSSION OF LABORATORY RESULTS

On the basis of lab and field results, the researchers concluded that Blastox<sup>®</sup> is appropriate for application on all steel

surfaces to be painted, with the exception of red iron oxide pigmented systems, which require a sweep blast with unmodified abrasive prior to painting for immersion service. Subsequent field application on steel over six winters have revealed no coating failures related to use of the engineered abrasive.

## **DISCUSSION OF FIELD DEMONSTRATION**

A field demonstration of the technologies was held at the Corps of Engineers Portland District, Dexter Dam Site, Tainter Gate No. 1, which is located near Dexter, OR. The LBP on the dam gate was removed by abrasive blasting with the engineered abrasive. An experienced painting contractor performed all LBP removal work under USACERL direction.

The TDJ Group supplied the abrasive blast media. The abrasive blast mixtures supplied were preblended at a rate of 20% Blastox<sup>®</sup> by weight in the following abrasives:

- copper slag
- nickel slag
- coal slag
- silica sand

The dam gate was divided into eight sections, one for each experiment. The four abrasive media types were used with both a traditional dry abrasive blast technology and the TORBO wet abrasive blast method (Figure 1). A simple containment system was constructed to collect all waste produced (Figure 2).

A contractor, RCI Environmental, conducted personal and area air monitoring for lead. USACERL documented the operating parameters for each technology, including removal rates, surface profiles, waste analyses, and the adhesion of new paint system.

## **RESULTS OF THE FIELD DEMONSTRATION**

### **TCLP ANALYSIS OF THE WASTE**

The Toxicity Characteristic Leaching Procedure was performed on samples of the waste from each of the experiments with the dry abrasive blast method. Because the abrasive media from the demonstration of the TORBO wet abrasive blast system could not be easily segregated, the four abrasive media were combined into a single waste stream and analyzed as a single sample. Two sets





FIGURE 1. OPERATION OF THE TORBO WET ABASIVE BLAST SYSTEM



FIGURE 2. VIEW OF THE CONTAINMENT STRUCTURE AT THE FIELD SITE



of samples were taken at the site and analyzed independently: one by USACERL and one by the TDJ Group. The results are shown in Table 1. (Note that the level of leachable lead to cause the waste to be classified as hazardous is 5 ppm.)

The total lead in the blast media ranged from 3,387 to 4,161 parts per million (ppm), indicating a relatively low level of lead in the paint. The data shows that the engineered abrasive controlled the leachability of the lead sufficiently to prevent the waste from being classified as hazardous. The results for both independent tests were similar, increasing the confidence in the results.

TABLE 1. TCLP ANALYSIS RESULTS

Sample	USACERL Results (mg/L)	TDJ Results (mg/L)
Coal slag, dry	<0.05*	0.13
Nickel slag, dry	<0.05	0.14
Silica sand, dry	<0.05	0.26
Copper slag, dry	<0.05	0.15
Combined wet media	NA	0.14
*Detection limits of the TCLP are 0.05 mg/L		

#### COATING INSPECTION AFTER 19 MONTHS IN SERVICE

USACERL personnel revisited the site to evaluate the coating performance after 19 months of service. Initial observation revealed a few localized spots of rust approximately 4 in. in diameter. The rust was caused by broken blisters and there was dense small blisters in the rusted areas. Once the small amount of paint on the rusted areas was removed, it was noted that a grinder had been used in these areas prior to painting.

#### COST AND BENEFIT ANALYSIS

A cost analysis of the use of Blastox<sup>®</sup> as an additive to blast media to stabilize LBP waste after removal was completed using data from the field demonstration (Table 2). Cost factors presented are based on actual contractor costs and are compared to actual government estimates. The term "capital facilities" refers to the capital investment in this technology (e.g. blast apparatus). Consumables refers to the blast media additives, tarps, and covers and packaging required for disposal. Environmental testing refers to required tests such as air

monitoring (both personal and area), XRF testing and TCLP waste analyses.

The information in Table 2 shows that the use of Blastox<sup>®</sup> can yield an immediate and relevant savings for removing lead-based paint from steel structures such as dam gates. This is based in the significant savings in disposal costs of a nonhazardous waste. The savings are \$0.93-3.04/sq.ft. of blast cleaned steel surface. The use of the TORBO wet abrasive blasting system can increase savings even further by reducing the level of containment required from a 100% to an 85% wind screen. This could further reduce the cost per square foot an additional \$1.00 to \$1.50.

## **CONCLUSIONS**

The demonstration successfully evaluated the composition, performance, and cost effectiveness of using an engineered abrasive containing Blastox<sup>®</sup> for removal of lead-based paint from steel structures. The waste was stabilized so that it would not fail the Toxicity Characteristic Leaching Procedure with lead leached at a level greater than 5 ppm. Therefore, the waste was classified as nonhazardous and a significant savings was realized, compared to the cost of disposal of hazardous waste.

TABLE 2. SAVINGS IN PRESENT VALUE DOLLARS ON STEEL STRUCTURES.

Cost Factors	Blast Media Without Blastox <sup>®</sup>	With Blastox <sup>®</sup> Additive at \$0.25/lb (20% mixing)
Capital Facilities <sup>1</sup>	\$40.00/site hour	\$40.00/site hour
Labor <sup>2</sup>	\$280.00/site hour	\$280.00/site hour
Consumables <sup>3</sup>	\$70.00/site hour (containment) \$67.00/site hour ( <u>crane rental</u> ) \$137.00/site hour	\$102.00/site hour (containment) \$67.00/site hour ( <u>crane rental</u> ) \$169.00/site hour
Environmental Testing <sup>4</sup>	\$151.00	\$151.00
Subtotal	\$608.00/site hour	\$640.00/site hour
Removal Rate <sup>5</sup>	100 sq ft/hour	100 sq ft/hour
Removal Cost	\$6.08/sq ft	\$6.40/sq ft
Disposal Cost <sup>6</sup>	\$1.40 - \$3.60/sq ft (\$350-\$900/ton)	\$0.15 - \$0.24/sq ft (\$35.21-\$55.01/ton)
Total Cost	\$7.48 - \$9.68/sq ft	\$6.55-\$6.64/sq ft
Savings		\$0.93 - \$3.04/sq ft
Notes:		
1. Capital rates of recovery are from actual contractor costs and government cost estimate detail sheets. Costs for investment are amortized over 7 years for depreciation, and assume a 2000-hour site year.		
2. Labor is quoted from actual contractor costs or derived from government cost estimate sheets.		
3. Consumables are based on items used up in the job process. Blastox <sup>®</sup> is factored into this number based on its rate of application and percent by weight in the blast media. Abrasive blasting of steel required 8 lb of abrasive per square foot cleaned.		
4. Environmental testing includes air monitoring (both personal and area), XRF, and TCLP tests.		
5. Removal rate varies depending on the size of equipment and the height and complexity of the structure.		
6. Disposal costs for hazardous wastes were supplied by the Marketing Department, Chemical Waste Management, Inc., Oakbrook, IL. Costs for nonhazardous waste reflect typical costs from 12 states (Solid Waste Digest, October, 1993, Chartwell Information Publisher, Inc., Alexandria, VA), and supplementary information from four additional states. The higher end of the range of disposal costs reflects per unit costs of the disposal of small quantities of waste (less than 5 tons). Lower unit disposal costs reflect disposal of bulk wastes from larger projects.		

<sup>1</sup> Hock, Vincent., Curt M. Gustafson, and Susan A. Drozd, *Demonstration of Lead-Based Paint Removal and Chemical Stabilization Using Blastox<sup>®</sup>*, Technical Report (TR) 96/20/ADA319807 (U.S. Army Construction Engineering Research Laboratories [USACERL], October 1996). Note: Blastox<sup>®</sup> is a product of the TDJ Group, Inc., 760-A Industrial Dr., Cary, IL 60013, tel. (847) 639-1113.

<sup>2</sup> Journal of Protective Coatings and Linings, May 1996.